Journal of Pediatric Surgery 57 (2022) 208–215

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg.org

Effect of surgeon volume on pediatric thyroid surgery outcomes: A systematic review

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ARTICLE INFO

Article history:
Received 2 June 2021
Revised 26 November 2021
Accepted 1 December 2021

Keywords:
Pediatric thyroid surgery
Thyroidectomy
Surgeon volume
Systematic review
Surgical outcomes
Volume outcome relationship

ABSTRACT

Background: Pediatric thyroidectomy has been identified as a surgical procedure that may benefit from concentrating cases to high-volume surgeons. This systematic review aimed to address the definition of "high-volume surgeon" for pediatric thyroidectomy and to examine the relationship between surgeon volume and outcomes.
Methods: PubMed, Embase, Cochrane Library, Scopus, Web of Science, ClinicalTrials.gov, and OpenGrey databases were searched for through February 2020 for studies which reported on pediatric thyroidectomy and specified surgeon volume and surgical outcomes.
Results: Ten studies, encompassing 6430 patients, were included in the review. Five single-center retrospective studies reported only on high-volume surgeons, one single center retrospective study reported on only low-volume surgeons, and four national database studies (2 cross sectional, 2 retrospective reviews) reported outcomes for both high-volume and low-volume surgeons. Majority of patients underwent total thyroidectomy (54.9%); common indications for surgery were malignancy (41.7%) and hyperthyroidism/thyroiditis (40.5%). Rates of transient hypocalcemia (11.4% - 74.2%), transient recurrent laryngeal nerve injury (0% - 9.7%), and bleeding (0.5% - 4.3%) varied across studies. Definitions for high-volume pediatric thyroid surgeons ranged from ≥9 annual pediatric thyroid operations to >200 annual thyroid operations (with >30 pediatric cases). Four studies reported significantly better outcomes, including lower post-operative complications and shorter length of hospital stay, for patients treated by high-volume surgeons.
Conclusions: Despite significant variation in caseloads to define volume, pediatric thyroid patients have generally better outcomes when operated on by higher volume surgeons. Concentration thyroidectomy cases to a smaller cohort of surgeons within pediatric practices may confer improved outcomes.
Level of evidence: Systematic Reviews and Meta-Analyses; Level IV

1. Introduction

While less common than for adults, children undergo total or partial thyroidectomy for a variety of indications including nodules, malignancy, Graves' disease, thyroid goiter, and multiple endocrine neoplasia syndromes [1,2]. Pediatric patients with thyroid malignancy more commonly present with metastatic and advanced disease compared to adults [3–5]. Furthermore, pediatric patients undergoing thyroidectomy have been reported to incur higher rates of operative complications than adult patients [6–10].

Several studies have shown a positive association with higher surgeon volume and improved patient outcomes (e.g., length of stay, recurrent laryngeal nerve injury) in adult thyroidectomy and parathyroidectomy [10–13]. The 2015 American Thyroid Association (ATA) guidelines for thyroid cancer care in children recommended that children be operated upon by experienced thyroid surgeons [14]. The ATA further references "experienced" as surgeons who

Abbreviations: APSA, American Pediatric Surgical Association; ATA, American Thyroid Association; NIS, National Inpatient Sample; NHLBI, National Heart Lung and Blood Institute; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses; PHIS, Public Health Information System; QA, Quality Assessment; RLN, Recurrent Laryngeal Nerve.

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https://doi.org/10.1016/j.jpedsurg.2021.12.005
0022-3468/

perform 30 or more cervical endocrine procedures annually [6,9]. In 2020, the American Pediatric Surgical Association (APSA) Cancer Committee also noted the benefits of referring children with differentiated thyroid carcinoma to surgeons with "extensive experience" in performing cervical procedures, though no case threshold was proposed to define such experience [15].

In addition to considerable heterogeneity in definitions of "high-volume" among surgeons performing pediatric thyroid surgery, there is a lack of comparable multi-center data. Our aim was to conduct a systematic review to address the definition of "high-volume", and to further examine the relationship between surgeon volume and outcomes after pediatric thyroidectomy.

2. Methods

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [16]. This study was not registered; a specific review protocol was not prepared but data extracted are outlined below.

2.1. Eligibility and search strategy

This review was comprised of studies that included pediatric patients who underwent thyroidectomy and reported the operative volume of the surgeons involved in the cases examined. Surgeon volume was defined as number of thyroid operations (total or partial thyroidectomy, with or without lymph node dissection) per year. All indications for thyroid surgery were included. Primary outcomes of interest included rates of postoperative hypocalcemia, permanent hypoparathyroidism, transient and permanent recurrent laryngeal nerve (RLN) injury, and major bleeding.

We examined PubMed, Embase, Cochrane Library, Scopus, Web of Science, ClinicalTrials.gov, and OpenGrey for our search. Search terms and adaptations are outlined in Supplementary Table 1. The initial query was developed in consultation with a library scientist and refined to ensure that cornerstone articles appeared in the search results. The final search was conducted in February 2020. Articles were included if they reported a thyroid case per year threshold and self-reported as high-volume surgeons, low-volume surgeons, or included separate analysis of both high- and low-volume surgeons. Studies that only reported hospital volume and not surgeon volume, did not report on pediatric outcomes, or were not available in English language were excluded.

2.2. Data extraction and analysis

Rayyan QCRI software was used to collect, organize, and mange titles [17]. Titles and abstracts of published articles identified were reviewed by two independent reviewers (SO, MI) with adjudication provided by a third author (MVR or JR). Three authors (SO, MI, PG) reviewed full text articles and extracted data on defined surgeon volumes, procedures performed, patient demographics, and rates of all clinical outcomes after thyroid surgery.

Outcomes of interest (transient hypocalcemia, permanent hypoparathyroidism, transient RLN injury, bleeding) were reported as defined by each individual study. Study definitions varied and are listed in Supplementary Table 2. Studies that did not report rates of follow up were unable to reliably distinguish between transient and permanent complications; based on this limitation complications of hypocalcemia and RLN injury were not divided into transient and permanent for studies without defined follow-up. Additional, not pre-specified demographic, outcome, or surgeon data that was reported by multiple studies was extracted for qualitative comparison.

2.3. Quality assessment

Two independent reviewers (SO, MI) appraised each study using the National Institutes of Health National Heart Lung and Blood Institute (NHLBI) Study Quality Assessment (QA) Tools [18]. Discrepancies in quality appraisal were resolved through adjudication with a third author (MVR). The studies were evaluated using the quality assessment tool that best fit the study description (observational cohort and cross-sectional studies or case series studies). Following the NHLBI reported guidelines for the QA tools, studies with a "fatal flaw" that introduced significant risk of bias (such as concerns about internal validity, selection bias, and unaccounted for confounding variables) were deemed poor quality; fair studies were classified as those with some risk of bias but none that severely impaired the interpretation of the study; good studies either clearly accounted for or contained low risk of bias.

2.4. Statistical analysis

Point estimates and their 95% confidence intervals were calculated for demographic data, surgical indication, and type of operation. To make estimates feasible surgical indications were classified into three categories: "malignancy", "hyperthyroidism/thyroiditis", and "other". The category of "malignancy" included malignancy, nodulectomy, and MEN2 prophylaxis. "Hyperthyroidism/thyroiditis" included goiter, Graves' disease, Hashimoto's thyroiditis, thyroiditis, and hyperthyroidism. The surgical indication category of "other" included benign neoplasm, thyroid cyst, completion surgery, and other/unspecified indications. Procedure type was dichotomized into "total thyroidectomy" (included total thyroidectomy, substernal thyroidectomy, and prophylactic thyroidectomy) and "other". Point estimates and analyses were performed using R (R Core Team, 2019). Descriptive analyses were conducted in Excel v. 16.42.

3. Results

3.1. Study selection

After removing duplicates, 57 potential references were obtained on initial search. Following abstract screening, 18 full-text articles were assessed, of which 10 studies were eligible for inclusion in review and pooled analyses [3,6,9,19-25]. The PRISMA diagram outlining each step of inclusion and exclusion is provided in Supplementary Figure 1.

3.2. Quality assessment

Of the 10 studies, 5 were rated as good, 4 as fair, and 1 as poor. Studies included single institutional case series ($n = 5$), national database cross-sectional studies ($n = 3$), a national database cohort study ($n = 1$), and a single institution case control study ($n = 1$). Primary weaknesses included reported low follow-up rates, non-standardized definitions of outcomes assessed, and lack of controlling for confounding factors that may bias analysis of surgeon-volume effect on outcomes. One study had majority of patients followed through 6 months[22], 1 study reported mean follow-up of 2.7 years[21], 1 study had greater than 3 years of follow-up on most patients[25], 4 studies had no follow-up beyond hospital visit[3,6,9,24], 1 study had hospital re-admission data through 90 months but was limited by patients being readmitted to hospitals in the PHIS database[23], 1 study reported complete follow-up of patients but did not specify a timeframe[19], 1 study commented on "long term follow-up" but did not reference a time frame or rates of patient adherence[20]. Further details on the quality appraisal are included in Table 1.

Table 1
Data sources and quality assessment of included studies.

Source	Study Design	Data Collection Site	Centers included in data	Years data collected	Evidence Quality Rating[a]	Quality assessment[b]
Single-center studies						
Baumgarten et al., [19]	Retrospective Review of Single Center	Children's Hospital of Philadelphia, Philadelphia, PA, USA	1	2009–2017	4	Good
Breuer et al., [20]	Retrospective Review of Single Center	Yale New Haven Children's Hospital, New Haven, CT, USA	1	2002–2010	4	Good
Bussieres et al., [21]	retrospective cohort review of single center	center hospitalier universitaire sainte-justine, montreal, quebec, ca	1	2006 - 2015	3	Poor[c]
Chen et al., [22]	Retrospective Review of Single Center	Massachusetts General Hospital, Boston, MA, USA	1	1992–2013	4	Fair
Elfenbein et al., [24]	Retrospective Review of Single Center	University of Wisconsin Health University Hospital, Madison, WI, USA	1	2009–2013	4	Good
Wood et al., [25]	Retrospective Review of Single Center	The Children's Hospital, Aurora, CO, USA	1	1995–2009	4	Fair
Multi-center studies						
Al-Qurayshi et al., [3]	Retrospective Review of National Data Base	Nationwide Inpatient Sample	~ 1000 hospitals	2003–2010	3	Good[c]
Drews et al., [23]	Retrospective Review of National Data Base	Pediatric Health Information System	52 Children's Hospitals	2005–2016	3	Good[c]
Sosa et al., [9]	Cross-sectional analysis of National Data Base	Healthcare Cost and Utilization Project Nationwide Inpatient Sample database	~ 1000 hospitals	1999–2005	4	Fair[c]
Tuggle et al., [6]	Cross-sectional analysis of National Data Base	Healthcare Cost and Utilization Project Nationwide Inpatient Sample database	230 Hospitals, 448 Surgeons	1999–2005	4	Fair[c]

[a] Assess using Quality Rating Scheme for Studies and Other Evidence; 1- Properly powered and conducted randomized clinical trial; systematic review with meta-analysis, 2- Well-designed controlled trial without randomization; prospective comparative cohort trial, 3- Case-control studies; retrospective cohort study, 4- Case series with or without intervention; cross-sectional study, 5- Opinion of respected authorities; case reports.
[a] Assessed using National Institutes of Health National Heart Lung and Blood Institute (NHLBI) Study Quality Assessment (QA) Tools.
[a] Studies evaluated as Observation Cohort and Cross-Sectional Studies; all other studies evaluated as Case Series.

3.3. Patient demographics

The baseline demographic and disease characteristics of the patients from each included study are detailed in Table 2. Overall, the majority of cohorts included predominant female patients (78.2% female), of early teen age (range of reported medians 13–15, range of reported means 9.7–15.4). Three studies included patients older than 18 as pediatric based on their center's case history or being treated at a Children's hospital 19,[23–25]. The majority of thyroid surgeries included across all studies were performed for malignancy (41.7%) or for various underlying etiologies of hyperthyroidism/thyroiditis (40.5%). Most patients included in the review underwent total thyroidectomy (54.9%). The four national database studies reported on race and household income with majority of patients being white (64.1%) and most families earning >$45,000 per year [3,6,9,23].

3.4. Definition of high and low surgeon volume

Of the 10 studies included in our review, 5 single-center studies classified themselves as high-volume surgeons with definitions ranging from > 50 annual thyroid operations (pediatric or adult) [22] to > 200 annual thyroid operations (of which > 30 were pediatric specific) [20] (Table 3). Another single-center study self-declared to be a low annual surgeon volume center with surgeons performing ≤ 9 pediatric thyroid surgeries per year [21]. Using multicenter children's hospital data, a review of the Pediatric Health Information System (PHIS) by Drews et al. defined the top tertial of surgeons performing pediatric thyroidectomy as high-volume (≥ 9 thyroid cases per year) [23]. Al-Qurayshi et al. proposed an intermediate volume definition of 3–30 thyroidectomies per year which could be more achievable for surgeons practicing at centers outside of tertiary academic hospitals [3]. Eight of the ten studies had high surgeon-volume definitions that were based on annual number of thyroidectomies (range 9 – 200) regardless of adult or pediatric patients.

3.5. Outcomes

Table 3 displays reported rates of thyroidectomy postoperative complications of interest. Rates of transient hypocalcemia varied across studies; two national database studies reported a range of 9.3% [9] to 74.2% [3] for transient hypocalcemia. Notably, the single-center study that was self-reported as low-volume had a rate of transient hypocalcemia (13.6%) comparable to and lower than some of the high surgeon-volume single-center reports (range 11.4% [25] - 72.9% [19]). Notably the studies had significant variations in defining and monitoring hypocalcemia; some studies classified transient hypocalcemia based only on a lab value [19,21,23], some required a lab finding and symptoms or supplementation [20,24-26]. Database studies [3,6,9] relied on "hypocalcemia" ICD-9 coding which are likely to have significant use and definition variability across centers. For permanent hypocalcemia/hypoparathyroidism, 4 single-center studies used a similar definition of lab evidence and supplementation required beyond 6 months and they reported rates of 0.5%, 0.6%, 3.2%, and 0% 19,[24–26].

Transient RLN injury rates were more consistent across studies. Among the six studies that reported RLN injury rates, all were under 10% [19-22,24,25]. Al-Qurayshi et al. reported the highest rate of permanent RLN injury of 8.6% [3] with 7 additional studies reporting rates less than 2.5% [19–25]. Bleeding rates were also low across studies (0% - 4.3%). The PHIS database review by Drews et al. reported data on the largest number of patients (3149) from 52 children's hospitals over the most contemporary time period (2005–2016) and found rates of hypocalcemia to be 15.5%, RLN injury to occur at 1%, and bleeding to occur at 0.5% [23].

Table 2
Demographic summary of 10 studies included in this systematic review of pediatric thyroidectomy patient outcomes by surgeon volume.

Source	Pts, n	Definition of Pediatric patients	Age, years	% Female	Race / Ethnicity[a]	Income / Health Insurance[a]	Indication for Surgery[a]	Operation Type[a]
Single-center studies								
Baumgarten et al., [19]	464	all patients undergoing thyroid surgery at Pediatric Thyroid Center	Median 15, Range 2–24	80	NR	NR	38% Malignancy, 28% Unspecified, 27% Graves' disease, 6% Completion surgery, 2% MEN2 prophylaxis	72% TT, 26% PT, 2% Completion surgery, 1% Other
Breuer et al., [20]	32	< 18 years	Mean 9.7, Range 3.4–17.9	81	NR	NR	100% Graves' disease	100% TT
Bussieres et al., 2019 [21]	98 (118 procedures)	< 18 years	Mean 11.8, SD 4.75	66	NR	NR	53% Thyroid nodule, 18% MEN2 prophylaxis, 17% Unspecified, 6% Hyperthyroidism, 6% Goiter	55% PT, 20% TT, 18% prophylactic TT, 7% Completion surgery
Chen et al., [22]	171 (186 procedures)	≤ 18 years	Mean 15.4, Range 2.5 - 18.9	82	NR	NR	75% Nodular disease, 12% Hyperthyroidism, 8% Completion surgery, 5% MEN2 prophylaxis	46% TT, 42% PT, 8% Completion surgery, 4% Nodulectomy
Elfenbein et al., [24]	31	< 18 years	Mean 14, Range 4–17	87	NR	NR	100% Graves' disease	100% TT
Wood et al., [25]	35	≤ 18, except for 1 special case (22 years)	Median 13, Mean 13, Range 3–22	69	NR	NR	71% Nodular disease, 17% Other, 6% Goiter, 3% Hashimoto's thyroiditis, 3% Graves' disease	54% TT, 46% PT
Multi-center studies								
Al-Qurayshi et al., [3]	644 (425 procedures)	< 18 years	Mean 13.8, SEM 0.2	77	58% White, 2% Black, 30% Hispanic, 4% Asian/Pacific Islander, 1% Native American, 6% Other	Annual Household Income: 17% 〈 39,000, 25% 39,000–47,999, 29% 48,000–62,999, 30% 〉 62,999	100% Malignancy	74% TT, 20% PT, 6% Substernal T
Drews et al., [23]	3149	≤ 21 years	Median 14, IQR 12–16	79	58% White, 12% Black, 3% Asian, 10% Other, 4% Unknown	Primary Healthcare Payer: 58% Private, 36% Government, 6% Other	28% Goiter, 23% Graves' disease, 22% Malignancy, 15% Nodule, 5% Other, 4% Hashimoto's thyroiditis, 3% MEN2 prophylaxis, 1% Thyroiditis	56% TT, 44% PT
Sosa et al., [9]	1199	< 17 years	Range 0–17	76	69% White, 8% Black, 14% Hispanic, 9% Other	Annual Household Income: 21% 〈 36,000, 25% 36,000–45,000, 27% 45,001–59,000, 27% 〉 59,000	27% Malignancy, 24% Goiter, 19% Benign neoplasm/ thyroid cyst, 15% Hyperthyroidism, 8% Thyroiditis, 7% Unspecified	51% PT, 40% TT, 9% Para T
Tuggle et al., [6]	607	≤ 17 years	Range 0–17	76	69% White, 9% Black, 14% Hispanic, 7% Other	Annual Household Income: 21% ≤ 35,999 25% 36,000–44,999 27% 45,000–58,999 27% ≥ 59,000	26% Malignancy, 74% Unspecified	51% PT 41% TT 8% Para T
Summary (Pooled estimates)[b]	Patients: 6430, Procedures: 6246		Range of means: 9.7 – 15.4, Range of medians: 13 - 15	78.2 (77.0, 79.2)	White: 64.1% (62.8%, 65.3%), Black: 8.9% (8.2%, 9.7%), Other: 27.1% (25.9%, 28.2%)		Malignancy: 41.7% (40.5%, 42.9%), Hyperthyroidism/thyroiditis: 40.5% (39.3%, 41.8%), Other: 17.8% (16.8%, 18.7%)	TT: 54.9% (53.7%, 56.2%), Other: 45.0% (43.8%, 46.3%)

[a] Based on rounding columns may not add to 100%.
[b] Estimates were calculated for variables that were reported by four or more studies. Estimates are reported as: point estimate (95% confidence interval).
[c] IQR, interquartile range; NR, not reported; Para T, parathyroidectomy; PT, partial thyroidectomy; SD, standard deviation; SEM, standard error of the mean; $T =$ thyroidectomy; TT, total thyroidectomy.

Table 3
Surgeon volume definitions and postoperative outcomes.

Source	Surgeon Volume High Volume Definition	Volume of Surgeons in study	Specialties of Surgeons	Patients, n	Transient Hypocalcemia (%)	Permanent Hypoparathyroidism (%)	Transient RLN Injury (%)	Permanent RLN Injury (%)	Bleeding (%)
Single-center studies									
Baumgarten et al., [19]	> 30 pediatric thyroid surgeries / year	High	Single center: Pediatric surgeon, Pediatric endocrine surgeon	464	72.9%	0.6%	1.9%	0.4%	1.3%
Breuer et al., [20]	> 200 thyroidectomies / year, > 30 pediatric thyroid surgeries / year	High	Single center: "high volume" endocrine surgeon & pediatric surgeon together	32	18.8%	0.0%	3.1%	0.0%	0.0%
Bussieres et al., [21]	> 10 pediatric thyroid surgery cases (average) / year	Low	Single center: 81% single pediatric surgeon, 15% pediatric otorhinolaryngologists, 4% other pediatric general surgeons	98	13.6%	1.7%	1.7%	2.5%	1.0%
Chen et al., [22]	> 50 thyroid operations (peds and/or adult) / year	High	Single Center: > 85% adult thyroid surgeons	171	12.9%	0.5%	1.6%	0.0%	NR
Elfenbein et al., [24]	> 100 thyroidectomies / year, or fellowship trained pediatric surgeon	High	Single center: endocrine surgeons or pediatric surgeons, occasionally co-surgeons	31	35.5%	3.2%	9.7%	0.0%	NR
Wood et al., [25]	> 100 thyroid surgeries / year	High	Single center: single endocrine surgeon on all cases, multiple pediatric co-surgeons	35	11.4%	0.0%	0.0%	0.0%	0.0%
Multi-center studies									
Al-Qurayshi et al., 2016 [3]	High: ≥ 31 thyroidectomies / year Intermediate: 3–30 thyroidectomies / year	High, Intermediate, & Low	81.1% General surgeon/other, 10.5% Otolaryngology, 8.4% Pediatric surgeon	644	74.2%[a]		8.6%[a]		4.3%
Drews et al., [23]	≥ 9 thyroid cases / year	High & Low	67% pediatric surgeon, 33% otolaryngologist	3149	15.5%[a]		1.0%[a]		0.5%
Sosa et al., [9]	> 30 cervical endocrine procedures (adults and/or children) / year	High & Low	27% Pediatric surgeon[b], 21% High-volume surgeon, 52% Other	1199	9.3%[a]		NR	NR	3.4%
Tuggle et al., [6]	> 30 cervical endocrine procedures (adults and/or children) / year	High & Low	27% Pediatric surgeon[b], 21% High-volume surgeon, 52% Other	607	NR	NR	NR	NR	NR

[a] Data source could not distinguish between transient and permanent events.
[b] Defined by the studies as ≥ 90% of practice involves patients ≤ 17 years old, in this study no pediatric surgeons met criteria for high-volume.
NR, not reported; RLN, recurrent laryngeal nerve.

3.6. Outcomes of high vs. low surgeon volume

Table 4 compares the four studies that reported outcomes for both high- and low- volume surgeons. Al-Qurayshi et al. reported that children whose thyroidectomies were performed by high-volume surgeons (≥ 31 thyroidectomies per year) had an 84% decrease in odds of complication compared to operations by low-volume surgeons (1–2 thyroidectomies per year). Notably, when controlling for race, thyroidectomy type, lymph node metastasis status, and lymph node dissection status, intermediate volume surgeons (3–30 thyroidectomies per year) had an 83% reduction in odds of complications compared to low-volume surgeons [3]. From this study, surgeon volume was the only characteristic significantly associated with outcomes after thyroidectomy; specialty practice and or training in pediatrics, otolaryngology, or general surgery did not change outcomes [3]. Similarly, Drews et al. reported a significant reduction in post-operative complications in total thyroidectomy patients treated by high-volume surgeons compared to low-volume surgeons (20.6% vs. 29.3%, $p = 0.001$) [23]. The studies of the National Inpatient Sample (NIS) by Sosa et al. and Tuggle et al. support this same trend and report lower, but not significantly different, rates of general and endocrine-specific complications in patients treated by high-volume surgeons. Drews et al. did not find surgeon volume to have an effect on hospital length of stay but the other three studies report significantly reduced length of stay for procedures performed by high-volume surgeons. Sosa et al. and Tuggle et al. also note a significant reduction in cost of surgery when performed by a high-volume surgeon [6,9]. Tuggle et al. reported that high-volume surgeons had a mean operation cost of $12,474 compared to $19,594 for low-volume surgeons (p <0.01) [6]. Using multivariate regression, Sosa et al. reported that cases done by low-volume surgeons accounted for $5146 worth of greater costs than cases done by high-volume surgeons (p <0.01) [9]. Each of these studies adjusted for demographic and clinical case characteristics and the association between patient outcomes and surgeon volume remained significant in two[3,23] of the four studies.

4. Discussion

Based on the high risk for complications and rarity of pediatric thyroidectomies, there have been calls for pediatric thyroid procedures to be performed only at high-volume centers and/or by high-volume surgeons [15,19,22,27]. This systematic review summarizes existing data on the relationship of surgeon-volume to pediatric thyroidectomy outcomes. A first notable finding is the wide variation in definitions of high-volume surgeons. High surgeon volume was defined differently by 9 of the 10 studies in our review. Although there was variation, there is general consensus that high-volume surgeons perform at least 30 thyroid-type surgeries (thyroidectomies, pediatric thyroid surgeries, parathyroid surgeries, cervical endocrine procedures) per year. Comparing a high-volume threshold of 30 thyroidectomies to data from national survey studies reveals that a small proportion of surgeons across the country performing pediatric thyroidectomies are considered high-volume. Review of 52 children's hospitals in the PHIS database reveals that between 2005 and 2016, two-thirds of pediatric thyroidectomies were done by surgeons who performed fewer than 9 thyroidectomies in the prior year [23]. Additionally, the NIS data shows that from 2003 to 2010 27% of pediatric thyroidectomies for thyroid cancer were done by surgeons who performed an average of only 1–2 thyroidectomies per year [3].

Although the definition of high-volume was inconsistent, studies consistently reported better postoperative outcomes in patients treated by high-volume surgeons compared to low-volume surgeons. Further, no clear additional protective effect was found

Table 4
Summary of studies that reported high vs. low volume surgeon outcomes.

Source	Surgeon Volume High Volume Definition	Patients, n	Operation analyzed	Post-operative complications			Length of stay		
				High-volume	Low-volume	P	High-volume	Low-volume	P
Al-Qurayshi et al., [3]	High: ≥ 31 thyroidectomies / year Intermediate: 3–30 thyroidectomies / year	644	Total thyroidectomy	14.3%	35.9%	OR 0.16 95% CI (0.05 - 0.51); $p = 0.002$	49.8% >1 day	67.9% >1 day	OR 0.36 95% CI (0.15–0.90); $p = 0.03$
Drews et al., [23]	≥ 9 thyroid cases / year	3149	Total thyroidectomy	20.6%	29.3%	$p = 0.001$	data not shown	data not shown	$p > 0.60$
Sosa et al., 2008[9]	> 30 cervical endocrine procedures (adults and/or children) / year	1199	Thyroid and parathyroid procedures	General complications 8.7%	13.4% Pediatric, 13.2% Other	NS	1.5 days	2.3 days Pediatric, 2 days Other	$p < 0.01$
				Endocrine-specific complications 5.6%	11.0% Pediatric, 9.5% Other	NS			
Tuggle et al., 2008[6]	> 30 cervical endocrine procedures (adults and/or children) / year	607	Thyroid and parathyroid procedures	General complications 8.7%	13.3%	NS	1.5 days	2.1 days	$p < 0.05$
				Endocrine-specific complications 5.6%	10.0%	NS			

NS, Not significant.

by studies examining surgeon specialization and/or hospital annual volume [9,23]. The surgeon-volume relationship has been established in adult thyroid surgery [10-13,28,29] with adult high-volume thresholds ranging from > 25 [30] to ≥ 50 thyroidectomies per year [31]. In 2020, the American Association of Endocrine Surgeons issued a “strong recommendation, moderate-quality evidence” that, when available, thyroidectomy should be performed by a high-volume thyroid surgeon, although they did not endorse a specific case threshold [32]. In pediatric specific thyroidectomy, Bussieres et al. challenged the call for only high-volume surgeons to perform thyroid surgery in children and noted that their tertiary academic center, with a five-decade history of thyroid surgery and low-volume surgeons, had rates of hypocalcemia and nerve injury comparable to that of the high-volume surgeons [21]. From their study, they concluded that surgeon volume alone is not the sole predictor of surgical outcomes, and suggest that lifetime number of thyroid cases, rather than cases per year, may have a role in defining high- versus low-volume surgeons.

Several of the studies offer methods for deciding how best to handle pediatric thyroid surgeries to increase patient safety while still allowing a range of centers to perform operations. One study suggests that all pediatric patients should be referred to high-volume pediatric thyroid centers [19]. Similarly, the American Thyroid Association 2015 guidelines for adult thyroidectomy recommended sending patients with extensive disease and concern for grossly invasive disease to high-volume surgeons [27]. The NIS reviews identified current social disparities with Black and Hispanic children and lower-income families having a lower proportion of their procedures performed by high-volume surgeons due to reduced access to high-volume surgeons [6,9]. While minimizing postoperative complications is paramount, undue restriction of which surgeons are recommended to perform pediatric thyroidectomies may disproportionately affect access to care of racial and ethnic minorities and low-income children. In order to balance improved patient outcomes with equitable access to surgeons, Al-Qurayshi et al. recommend surgeons complete an average of at least 3 cases per year to be considered “intermediate” volume. They demonstrated an 84% decrease in odds of complication compared to operations by lower-volume surgeons. Further, collaborative efforts to partner lower volume surgeons with higher-volume surgeons may facilitate access to care and confer benefits of having a higher-volume surgeon present.

Furthermore, development of and adherence to Clinical Practice Guidelines that direct postoperative lab surveillance and monitoring could also reduce postoperative complications across centers [19]. Based on the varied definitions of hypocalcemia from the included studies, we recommend applying the ATA definitions for adult post-operative hypoparathyroidism to guide care of pediatric patients [33]. These definitions differentiate biochemical hypocalcemia (below lower limit of center specific range) and clinical hypocalcemia (biochemical hypocalcemia AND symptoms/clinical signs) and set duration of 6 months as threshold for distinguishing transient from permanent hypocalcemia. In order to standardize detection of permanent complications, we recommend routine follow-up at 6 months post-thyroidectomy.

Aside from surgical volume, the reviewed publications all recommend and emphasize the value of a consistent and highly trained surgical team as a way to improve patient care. Each single center study shared a slightly different approach to their operative team, but all emphasized multiple specialties involved and concentrating cases with a few high-volume surgeons. Several centers endorse the use of a combined approach of children’s surgeons working with a high-volume specialty trained adult endocrine surgeon [20,22,24,25]. Dual surgeon teams have shown improved surgical outcomes (reduced estimated blood loss, reduced postoperative complications) and factors associated with reduced costs (shorter operating time, shorter hospital length of stay) across a variety of operations including mastectomy [34], spine surgery [35–39], and reconstructive surgery [40] . While this is an ongoing area of study and conversation in many fields [41], additional studies are required to analyze outcomes and costs of dual surgeon teams in pediatric thyroid surgery.

Baumgarten et al. raised concerns about the two-attending team with adult endocrine surgeons suggesting this strategy may neglect training institutions responsible for adequately preparing pediatric surgical specialists to be competent thyroid surgeons. Instead, they recommend every pediatric surgical trainee to be involved in at least 8–10 thyroid surgeries per year of training and use an apprentice strategy with a pediatric thyroid specialist during initial years of practice [19]. At our academic tertiary care center, we have found that having multiple attending surgeons present for thyroid surgical cases provides tremendous value to trainees through experience with a variety of technical pearls and vibrant discussions surrounding operative planning and approach. One option for low-volume centers, such as reported by Bussieres et al., is to concentrate pediatric thyroid cases with a single senior surgeon who trains a junior surgeon apprentice. Bussieres et al. also found that severe complications occurred in a specific subset of patients who were either very young or presented with extensive or advanced disease; they now employ a two-attending team of a pediatric general surgeon and pediatric otorhinolaryngologist for these cases [21]. As noted, we have adopted either a two-surgeon approach with most cases being staffed with either a senior-junior model or a multidisciplinary team of pediatric surgery and pediatric otorhinolaryngology present for most of the cases.

This study is limited by the quantity and quality of studies eligible for inclusion. The overall quality of the studies was fair to good, with one poor quality study; most studies were single center case series and national database cross-sectional studies. The range of high-volume thresholds set by each study limit this study’s ability to pool data and make broader conclusions. The relative heterogeneity or lack of specific definitions for outcomes of hypocalcemia, RLN injury, and bleeding limited the ability to pool data and perform comparison analyses. Only four studies reported outcomes for both high-volume and low-volume surgeons limiting the ability to pool and directly compare surgeon volume to outcomes. Further, the national database studies are also at risk of not accounting for confounding variables, such as pre- and post-operative management of patients, rather than surgeon volume influencing outcomes.

5. Conclusion

We identified 10 studies that described outcomes of pediatric patients undergoing thyroidectomy. This review demonstrates that pediatric thyroid patients have generally better outcomes when operated on by high-volume surgeons, but there is significant variation in definitions of caseloads to define high-volume. As surgical specialties and the field of pediatrics continues to sub-specialize, pediatric thyroid surgery should adopt a collaborative care approach and may consider concentrating cases to high-volume surgeons.

Declaration of Competing Interest

The authors have no competing interests to declare.

Financial Support

No funding was received for this article.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpedsurg.2021.12.005.

References

[1] Hanba C, Svider PF, Siegel B, Sheyn A, Shkoukani M, Lin H-S, et al. Pediatric Thyroidectomy: Hospital Course and Perioperative Complications. Otolaryngology–Head and Neck Surgery 2017;156:360–7.
[2] Kundel A, Thompson GB, Richards ML, Qiu LX, Cai Y, Schwenk FW, et al. Pediatric endocrine surgery: a 20-year experience at the Mayo Clinic. J Clin Endocrinol Metab 2014;99:399–406.
[3] Al-Qurayshi Z, Hauch A, Srivastav S, Aslam R, Friedlander P, Kandil E. A National Perspective of the Risk, Presentation, and Outcomes of Pediatric Thyroid Cancer. JAMA Otolaryngol Head Neck Surg 2016;142:472–8.
[4] Thompson GB, Hay ID. Current strategies for surgical management and adjuvant treatment of childhood papillary thyroid carcinoma. World J Surg 2004;28:1187–98.
[5] Dinauer CA, Breuer C, Rivkees SA. Differentiated thyroid cancer in children: diagnosis and management. Curr Opin Oncol 2008;20:59–65.
[6] Tuggle CT, Roman SA, Wang TS, Boudourakis L, Thomas DC, Udelsman R, et al. Pediatric endocrine surgery: Who is operating on our children? Surgery 2008;144:869–77.
[7] Al-Qurayshi Z, Robins R, Hauch A, Randolph GW, Kandil E. Association of Surgeon Volume With Outcomes and Cost Savings Following Thyroidectomy: A National Forecast. JAMA Otolaryngol Head Neck Surg 2016;142:32–9.
[8] Lee JA, Grumbach MM, Clark OH. The Optimal Treatment for Pediatric Graves' Disease Is Surgery. J Clin Endocrinol Metab 2007;92:801–3.
[9] Sosa JA, Tuggle CT, Wang TS, Thomas DC, Boudourakis L, Rivkees S, et al. Clinical and economic outcomes of thyroid and parathyroid surgery in children. J Clin Endocrinol Metab 2008;93:3058–65.
[10] Sosa JA, Bowman HM, Tielsch JM, Powe NR, Gordon TA, Udelsman R. The importance of surgeon experience for clinical and economic outcomes from thyroidectomy. Ann Surg 1998;228:320–30.
[11] Chen H, Zeiger MA, Gordon TA, Udelsman R. Parathyroidectomy in Maryland: effects of an endocrine center. Surgery 1996;120:948–52 discussion 52-3.
[12] Mittendorf EA, McHenry CR. Complications and sequelae of thyroidectomy and an analysis of surgeon experience and outcome. Surg Technol Int 2004;12:152–7.
[13] Sosa JA, Mehta PJ, Wang TS, Yeo HL, Roman SA. Racial disparities in clinical and economic outcomes from thyroidectomy. Ann Surg 2007;246:1083–91.
[14] Francis GL, Waguespack SG, Bauer AJ, Angelos P, Benvenga S, Cerutti JM, et al. Management Guidelines for Children with Thyroid Nodules and Differentiated Thyroid Cancer. Thyroid 2015;25:716–59.
[15] Christison-Lagay ER, Baertschiger RM, Dinauer C, Francis GL, Malek MM, Lautz TB, et al. Pediatric differentiated thyroid carcinoma: An update from the APSA Cancer Committee. J Pediatr Surg 2020;55:2273–83.
[16] Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339:b2535.
[17] Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev 2016;5:210.
[18] National Heart L, and Blood Institute. Study Quality Assessment Tools, https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools; 2020.
[19] Baumgarten HD, Bauer AJ, Isaza A, Mostoufi-Moab S, Kazahaya K, Adzick NS. Surgical management of pediatric thyroid disease: Complication rates after thyroidectomy at the Children's Hospital of Philadelphia high-volume Pediatric Thyroid Center. J Pedia Surg 2019;54:1969–75.
[20] Breuer CK, Solomon D, Donovan P, Rivkees SA, Udelsman R. Effect of patient age on surgical outcomes for Graves' disease: A case-control study of 100 consecutive patients at a high volume thyroid surgical center. Int J Pedia Endocrinol 2013 2013.
[21] Bussieres V, Roy S, Deladoey J, Rousseau E, St-Vil D, Piche N. Pediatric thyroidectomy: Favorable outcomes can be achieved by a multidisciplinary team of pediatric providers. J Pediatr Surg 2019;54:527–30.
[22] Chen Y, Masiakos PT, Gaz RD, Hodin RA, Parangi S, Randolph GW, et al. Pediatric thyroidectomy in a high volume thyroid surgery center: Risk factors for postoperative hypocalcemia. J Pediatr Surg 2015;50:1316–19.
[23] Drews JD, Cooper JN, Onwuka EA, Minneci PC, Aldrink JH. The relationships of surgeon volume and specialty with outcomes following pediatric thyroidectomy. J Pediatr Surg 2019;54:1226–32.
[24] Elfenbein DM, Katz M, Schneider DF, Chen H, Sippel RS. Thyroidectomy for Graves' disease in children: Indications and complications. J Pediatr Surg 2016;51:1680–3.
[25] Wood JH, Partrick DA, Barham HP, Bensard DD, Travers SH, Bruny JL, et al. Pediatric thyroidectomy: a collaborative surgical approach. J Pediatr Surg 2011;46:823–8.
[26] Chen YF, Masiakos PT, Gaz RD, Hodin RA, Parangi S, Randolph GW, et al. Pediatric thyroidectomy in a high volume thyroid surgery center: Risk factors for postoperative hypocalcemia. J Pediatr Surg 2015;50:1316–19.
[27] Haugen BR, Alexander EK, Bible KC, Doherty GM, Mandel SJ, Nikiforov YE, et al. American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer: The American Thyroid Association Guidelines Task Force on Thyroid Nodules and Differentiated Thyroid Cancer. Thyroid 2015;26:1–133 2016.
[28] Gourin CG, Tufano RP, Forastiere AA, Koch WM, Pawlik TM, Bristow RE. Volume-Based Trends in Thyroid Surgery. Archiv Otolaryngol–Head Neck Surg 2010;136:1191–8.
[29] Meltzer C, Klau M, Gurushanthaiah D, Tsai J, Meng D, Radler L, et al. Surgeon volume in thyroid surgery: Surgical efficiency, outcomes, and utilization. Laryngoscope 2016;126:2630–9.
[30] Adam MA, Thomas S, Youngwirth L, Hyslop T, Reed SD, Scheri RP, et al. Is There a Minimum Number of Thyroidectomies a Surgeon Should Perform to Optimize Patient Outcomes? Ann Surg 2017;265:402–7.
[31] Nouraei SA, Virk JS, Middleton SE, Aylin P, Mace A, Vaz F, et al. A national analysis of trends, outcomes and volume-outcome relationships in thyroid surgery. Clin Otolaryngol 2017;42:354–65.
[32] Patel KN, Yip L, Lubitz CC, Grubbs EG, Miller BS, Shen W, et al. The American Association of Endocrine Surgeons Guidelines for the Definitive Surgical Management of Thyroid Disease in Adults. Ann Surg 2020;271:e21–93.
[33] Orloff LA, Wiseman SM, Bernet VJ, Fahey TJ, 3rd Shaha AR, Shindo ML, et al. American Thyroid Association Statement on Postoperative Hypoparathyroidism: Diagnosis, Prevention, and Management in Adults. Thyroid 2018;28:830–41.
[34] Mallory MA, Losk K, Camuso K, Caterson S, Nimbkar S, Does Golshan M. Two is Better Than One" Apply to Surgeons? Comparing Single-Surgeon Versus Co–surgeon Bilateral Mastectomies. Ann Surg Oncol 2016;23:1111–16.
[35] Halanski MA, Elfman CM, Cassidy JA, Hassan NE, Sund SA, Noonan KJ. Comparing results of posterior spine fusion in patients with AIS: Are two surgeons better than one? J Orthop 2013;10:54–8.
[36] Kwan MK, Chiu CK, Chan CY. Single vs two attending senior surgeons: assessment of intra-operative blood loss at different surgical stages of posterior spinal fusion surgery in Lenke 1 and 2 adolescent idiopathic scoliosis. Eur Spine J 2017;26:155–61.
[37] Hayes JW, Feeley I, Davey M, Borain K, Green C. Comparison of a dual-surgeon versus single-surgeon approach for scoliosis surgery: a systematic review and meta-analysis. Eur Spine J 2021;30:740–8.
[38] Ames CP, Barry JJ, Keshavarzi S, Dede O, Weber MH, Deviren V. Perioperative Outcomes and Complications of Pedicle Subtraction Osteotomy in Cases With Single Versus Two Attending Surgeons. Spine Deform 2013;1:51–8.
[39] Shrader MW, Wood W, Falk M, Segal LS, Boan C, White G. The Effect of Two Attending Surgeons on the Outcomes of Posterior Spine Fusion in Children With Cerebral Palsy. Spine Deform 2018;6:730–5.
[40] Weichman KE, Lam G, Wilson SC, Levine JP, Allen RJ, Karp NS, et al. The Impact of Two Operating Surgeons on Microsurgical Breast Reconstruction. Plast Reconstr Surg 2017;139:277–84.
[41] Ellis R, Hardie JA, Summerton DJ, Brennan PA. Dual surgeon operating to improve patient safety. Br J Oral Maxillofac Surg 2021;59:752–6.